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SDSS J141624.08+134826.7: A NEARBY BLUE L DWARF FROM THE SLOAN DIGITAL SKY SURVEY

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ABSTRACT

We present the discovery of a bright ($J = 13.1$ mag) nearby L6 dwarf found in a search for L-type ultracool subdwarfs in the Sloan Digital Sky Survey (SDSS) Data Release 7. SDSS J141624.08+134826.7 exhibits blue near-infrared colors compared to other optically-typed L6 objects, but its optical and near-infrared spectra do not show metal-poor features characteristic of known L-type ultracool subdwarfs. Instead, SDSS J141624.08+134826.7 is probably a nearby example of the class of L dwarfs with low condensate opacities which exhibit unusually blue near-infrared colors for a given spectral type. Its deep 1.4 and 1.9 μm H_2O absorption bands, weak 2.3 μm CO feature, strong 0.99 μm FeH band, and shallow optical TiO and CaH bands resemble the spectra of other blue L dwarfs which are believed to have unusually thin or large-grained cloud structure. The luminosity of SDSS J141624.08+134826.7 implies that it is either a high-mass brown dwarf or a low mass star, depending on its age, and its UVW space motion suggests a thin-disk membership. With a spectrophotometric distance of 8.4 ± 1.9 pc, SDSS J141624.08+134826.7 is one of the nearest L dwarfs to the Sun and is therefore an excellent target for high resolution imaging, spectroscopic, and astrometric follow-up observations.

Subject headings: stars: low-mass, brown dwarfs — stars: individual (SDSS J141624.08+134826.7)

1. INTRODUCTION

Over the past 15 years several hundred L and T dwarfs have been found within ~ 100 pc of the Sun. Untangling the atmospheric and evolutionary properties of these objects as a function of mass, age, and metallicity is a leading goal of brown dwarf astrophysics. The rarest classes of ultracool dwarfs are particularly insightful because their extreme properties map the diversity of physical parameters that exist in nature.

One such class are the blue L dwarfs that have been identified by their outlying $J - K_S$ colors compared to normal L dwarfs (e.g., Cruz et al. 2003; Knapp et al. 2004; Folkes et al. 2007; Burgasser et al. 2008b). Several explanations have been invoked to account for these blue NIR colors. A reduced metallicity manifests as supressed NIR flux longward of ~ 1.2 μm as a result of increased collision-induced absorption by H_2 (Linsky 1969; Borysow et al. 1997), creating blue NIR colors. Unresolved cool companions may also produce abnormally blue NIR colors by adding disproportionally more J-band flux to a composite spectrum, especially when the primary is a late-M or L dwarf and the unseen companion is a T dwarf (e.g., Cruz et al. 2004; Liu et al. 2006; Burgasser et al. 2008a). Finally, variations in cloud structure are thought to affect the $J - K_S$ colors of L dwarfs by altering the condensate opacity (Knapp et al. 2004; Burgasser et al. 2008b).

In this Letter we report on the serendipitous discovery of SDSS J141624.08+134826.7 (hereafter SDSS J1416+1348), a bright L dwarf with blue NIR colors found in a search for ultracool subdwarfs in the Sloan Digital Sky Survey (SDSS; York et al. 2000). Its spectrophotometric distance places it within 10 pc of the Sun.

2. A SEARCH FOR L-TYPE SUBDWARFS WITH SDSS

SDSS is an ongoing optical photometric and spectroscopic survey using a dedicated 2.5-m telescope at Apache Point Observatory. The seventh data release (DR7; Abazajian et al. 2009) recently marked the end of the second phase of the survey, SDSS II, and includes $\sim 11{,}600$ deg^2 of imaging data in u, g, r, i, and z photometric bands. Medium resolution ($R \equiv \lambda/\Delta\lambda \sim 2000$) spectroscopic observations from 3800-9200 Å were obtained for $\sim 9{,}400$ deg^2 of sky for $\sim 460{,}000$ stars.

The SDSS photometric and spectroscopic database is a rich resource for identifying new cool and ultracool dwarfs (e.g., Leggett et al. 2000, Chiu et al. 2006, Bochanski et al. 2007). Recently Sivarani et al. (2009) found a peculiar L-type object in the SDSS spectral database, SDSS J125637.13-022452.4 (SDSS J1256-0224, sdL3.5), whose unique spectral, photometric, and kinematic properties suggest the object is an inner halo ultracool subdwarf (see also Burgasser et al. 2009). Metal-poor L dwarfs are quite rare in the solar neighborhood; only three other sdL-type objects are currently known (Burgasser et al. 2003, Burgasser 2004, Cushing et al. 2009).

In an effort to identify more L-type ultracool subdwarfs, we searched the SDSS spectral database for objects with similar colors and spectral features to SDSS J1256-0224. We selected all objects with late-type stellar spectral flags (SpecClass = "Star_Late") within the following color and magnitude limits (AB mags): $1.5 < i - z < 3.5$, $0.0 < r - i < 6.0$, and $i < 20.0$. The color

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selection criteria were defined to include objects that are slightly bluer than SDSS J1256-0224 (i–z = 1.7, $r - i$ = 2.4) and to allow for much redder red-optical colors. The magnitude criterion was set to exclude noisy spectra.

Altogether 1581 objects satisfied these criteria. We visually inspected each spectrum in search of L-type objects with strong TiO and CaH absorption features at $\sim$ 7100 Å and 6800 Å, respectively, which are characteristic of known L-type subdwarfs. These deep features contrast sharply with the shallow CaH and TiO absorption depths shortward of 7500 Å in the optical spectra of normal L dwarfs. Most of the objects in our sample were late-type M dwarfs with a small fraction being L dwarfs. We recovered the sdL3.5 object SDSS J1256-0224 but failed to find other similar ultracool subdwarfs.

We did, however, uncover a previously unknown bright late-type L dwarf, SDSS J1416+1348, which is the subject of this Letter. Its peculiar blue NIR colors are coincidentally characteristic of the ultracool subdwarfs we were searching for, but they were not a part of our search criteria. The SDSS fiber-fed spectrum of SDSS J1256-0224 was obtained on 13 March 2005 UT and has a median signal-to-noise ratio of 14 between 6300-9200 Å.

We obtained a low resolution ($R \sim 100$) 0.75-2.5 μm spectrum of SDSS J1416+1348 using the prism mode of the SpeX spectrograph (Rayner et al. 2003) mounted on the 3-m NASA Infrared Telescope Facility (IRTF) on the night of 4 April 2009 UT. The weather was poor with variable cirrus clouds and $\sim$ 1$''$.3 FWHM seeing. We obtained a total of 1440 s of exposure time with the 0$''$.8 slit width at an airmass of 1.03. Immediately afterwards we observed the A0V star HD 131951 for telluric correction. The data were reduced using version 3.4 of the Spextool data reduction package (Vacca et al. 2003, Cushing et al. 2004). The median signal-to-noise ratio of our final spectrum is 45 but reaches in excess of 100 in the J and H bandpasses.

3. ANALYSIS

3.1. *Spectral Classification*

The optical spectrum of SDSS J1416+1348 is presented in Figure 1 along with the spectra of L5-L8 dwarf templates from Kirkpatrick et al. (1999). The optical spectrum of SDSS J1416+1348 is most similar to the L6 dwarf 2MASS J0850359+105716 (2MASS J0850+1057) from 6300-9200 Å, although a good match to the L7 dwarf DENIS-P J0205.4–1159 is achieved from 6300-8000 Å. Based on the similarity to 2MASS J0850+1057, we assign SDSS J1256-0224 an optical spectral type of L6.0 $\pm$ 0.5.

Like field L dwarfs, SDSS J1416+1348 exhibits weak absorption features redward of 7500 Å. This is in contrast to the optical spectra of known L subdwarfs which exhibit deep TiO and CaH absorption bands from 6700-7200 Å. These enhanced features that are thought to be caused by a reduced metallicity (Bessell 1982). The optical TiO and CaH bands SDSS J1416+1348 appear to be slightly deeper than the field L dwarfs in Figure 1 and may be a sign that SDSS J1416+1348 is slightly metal-poor.

No Li I is observed in SDSS J1416+1348 (EW $\lesssim$ 2 Å) which suggests that it is a low-mass star or an old high mass brown dwarf by the lithium test (Magazzu et al. 1993), although another possibility is that SDSS J1416+1348 is a brown dwarf with a mass below the Li burning limit ($\sim$ 0.06 $M_\odot$; Burrows et al. 2001) but with a temperature cool enough ($\sim$ 1300-1600 K; Lodders 1999; Burrows & Sharp 1999) for lithium-bearing molecules like LiCl to form. Weck et al. (2004) derive mid-infrared LiCl opacities for brown dwarfs and show that LiCl may be detectable in late-L dwarfs at the level of a few percent at 15.8 μm. The brightness of SDSS J1416+1348 (§3.2) presents an excellent opportunity to search for LiCl; its detection would indicate that SDSS J1416+1348 is a brown dwarf while a non-detection would suggest that it is a high-mass brown dwarf or low-mass star.

Figure 2 shows our SpeX NIR spectrum of SDSS J1416+1348. As with normal L dwarfs, SDSS J1416+1348 exhibits deep H_2O absorption bands at 1.4 and 1.9 μm, CO absorption at 2.3 μm, and various atomic and molecular features blueward of 1.3 μm. Overplotted in the same figure is the NIR spectrum of the L6 dwarf 2MASS J10101480–0406499 (2MASS J1010–0406) from Reid et al. (2006), whose $J - K_S$ color of 1.9 mags places it near the mean $J - K_S$ color of L6 dwarfs (Figure 3, top panel). The most obvious difference between SDSS J1416+1348 and 2MASS J1010–0406 is the reduced flux of SDSS J1416+1348 longward of $\sim$ 1.3 μm. Other notable differences include significantly stronger 1.4 and 1.9 μm H_2O absorption bands in SDSS J1416+1348, a weakened CO bandhead at 2.3 μm, a strengthened FeH feature at 0.99 μm, and the absence of the 1.6 μm FeH absorption feature which is present in 2MASS J1010–0406 and most, but not all, L dwarfs. Also overplotted in Figure 2 is the NIR spectrum of 2MASS J11263991–5003550 (2MASS J1126–5003) from Burgasser et al. (2008b) (see also Folkes et al. 2007), which is a blue L4.5 dwarf that is believed to have thinner or larger-grained clouds compared to normal L dwarfs. SDSS J1416+1348 has a remarkably similar spectrum to 2MASS J1126–5003 and, when normalized to 1.2-1.3 μm as in Figure 2, only diverges from 2MASS J1126–5003 at $\gtrsim$ 2 μm.

We use the indices of Reid et al. (2001) and Geballe et al. (2002) to derive a NIR spectral type for SDSS J1416+1348. The K1, H_2O^A, and H_2O^B indices from Reid et al. (2001) yield NIR spectral types of L3.0 $\pm$ 1.0, L5.5 $\pm$ 3.5, and L5.5 $\pm$ 2, respectively. The 1.5 μm H_2O and 2.2 μm CH_4 indices from Geballe et al. (2002) yield NIR spectral types of L7.0 $\pm$ 1.0 and L7.5 $\pm$ 1.0. We compute uncertainties for the indices in a Monte Carlo fashion, incorporating spectral measurement errors and the intrinsic scatter in the SpT-index relations. The wide range of classifications reflects the peculiar spectrum of SDSS J1416+1348. We adopt the average and rms of the above values, L6pec $\pm$ 2, as the NIR spectral type.

3.2. *Photometric Distance*

We estimate a distance of 7.0 $\pm$ 1.4 pc to SDSS J1416+1348 using the J-band absolute magnitude-optical spectral type relations from Tinney et al. (2003). The error incorporates the uncertainty in the measured apparent magnitude, the rms uncertainty of the M_J-SpT relation, and the uncertainty in the spectral type. The K_S-band spectrophotometric distance of 9.7 $\pm$ 1.9 pc is consistent with the value derived using the J-band magnitude. However, because the absolute magnitude-SpT

relations were derived using "normal" L dwarfs, these relations are probably not as accurate for blue L dwarfs. We adopt the mean and rms of the J- and K_S-band spectrophotometric distances, 8.4 ± 1.9 pc, as our distance estimate for SDSS J1416+1348.

If the blue NIR colors of SDSS J1416+1348 are caused by reduced metallicity then we should employ subsolar metallicity absolute magnitude-SpT relations to estimate its distance. Using the relations from Cushing et al. (2009) we derive J-, H-, and K_S-band spectrophotometric distances of 10.6 ± 1.0 pc, 9.5 ± 1.0, and 8.1 ± 1.0 pc, respectively, with an unweighted mean and rms of 9.4 ± 1.3 pc, which is consistent with our solar-metallicity estimates. Even if SDSS J1416+1348 is a metal-poor L dwarf then it still appears to be located within 10 pc from the Sun (see also § 3.4).

3.3. *Physical Properties*

We fit the AMES-Dusty atmospheric models (Allard et al. 2001) to our IRTF/SpeX NIR spectrum to estimate the physical parameters of SDSS J1416+1348.[2] The AMES-Dusty models consider the limiting case of dust in chemical equilibrium with the gas phase. We fit the solar-metallicity grid of synthetic spectra spanning 1500 K $\leq T_{\rm eff} \leq$ 3400 K ($\Delta T_{\rm eff}$ = 100 K) and 4.0 $\leq$ log g (cgs) $\leq$ 6.0 (Δlog g = 0.5) using the method described in Bowler et al. (2009). The best-fitting model has an effective temperature of 2200 K and a surface gravity of 5.5 (hereafter written as [2200/5.5]; Figure 3, inset). For comparison we fit the NIR spectrum of 2MASS J1010–0406 (displayed in Figure 2), which has the same optical spectral type as SDSS J1416+1348 (L6) but has considerably redder NIR colors and is representative of "normal" L6 dwarfs. The best fitting model to 2MASS J1010–0406 is [1800/5.5]; the blue NIR spectrum of SDSS J1416+1348 yields a best-fitting model which is 400 K warmer than for normal L dwarfs. We obtain the same best-fitting models (as cited above) when we exclude the 1.5-1.7 μm spectral region, which contains an FeH feature that is missing from the model line lists.

We combine our IRTF/SpeX near-IR spectrum with the best-fitting [2200/5.5] AMES-Dusty model to construct the complete spectral energy distribution (SED). We flux-calibrate the SED using the 2MASS K_S-band photometry and our photometric distance. We then integrate the SED to measure the bolometric luminosity ($L_{\rm bol}$) using a Monte Carlo approach to account for the measurement errors (from the finite S/N of the NIR spectrum, the 2MASS-based flux calibration, and the photometric distance). To gauge the systematic impact of a mismatched atmospheric model we also use the [1800/5.5] AMES-Dusty model and find a ∼0.02 dex resulting uncertainty in $\log(L_{\rm bol}/L_\odot)$. Including the error in the distance, we find $\log(L_{\rm bol}/L_\odot)$ = –4.36 ± 0.21 dex.[3]

Based on the solar-metallicity evolutionary models of Burrows et al. (1997), we use the measured $L_{\rm bol}$ and assumed ages of 1, 3, and 10 Gyr to determine masses for SDSS J1416+1348 of 61 ± 9, 78 ± 3, and 80.9 ± 1.2 $M_{\rm Jup}$. Thus, the object appears to be right at the stellar/substellar boundary and is either a high-mass brown dwarf or a low-mass star assuming it is a single object. These masses are consistent with the non-detection of lithium in the optical spectrum.

3.4. *Space Motion*

The space motion of SDSS J1416+1348 can provide a clue about the physical origin of its blue NIR colors. Faherty et al. (2008) analyzed the kinematics of over 800 ultracool dwarfs and found that L dwarfs with unusually blue colors have kinematics consistent with the Galactic thick disk or halo. This suggests that metallicity and/or high surface gravity is the culprit of the blue colors for that population. Similarly, most ultracool subdwarfs discovered to date have thick disk or halo orbits (e.g., Burgasser et al. 2003; Cushing et al. 2009).

We measure the proper motion of SDSS J1416+1348 using relative astrometry derived from the imaging surveys DSS-2 (RI), 2MASS (JHK), SDSS (riz), and UKIDSS[4] ($YJHK$). We use SExtractor (Bertin & Arnouts 1996) to measure the positions of all objects in the original survey images and SCAMP (Bertin 2006) to determine an astrometric solution for each data set. After matching common objects between data sets, we compute the positional offset of SDSS J1416+1348 relative to well-detected (S/N > 10) reference stars within 3′. There are 4 to 21 such reference stars for every pair of images. For the relative astrometry between any two epochs, we adopt the mean and standard deviation of the offsets computed for all common reference objects. We validate these astrometric errors, which range from ∼ 30 mas for SDSS and UKIDSS to ∼ 300 mas for DSS-2, by confirming that our resulting fit to the motion of SDSS J1416+1348 has a reduced χ^2 value near unity. We find that we also need to include parallax motion in order to achieve a reasonable reduced χ^2, as the high quality UKIDSS and SDSS data show a clear deviation from simple proper motion. This is not surprising given SDSS J1416+1348's spectrophotometric distance of ∼ 8.4 pc. We fit for the proper motion and parallax using all $N(N-1)/2$ possible epoch pairs, employing the Levenbarg-Marquardt algorithm for least-squares minimization to perform the fit. To assess the uncertainty in our best-fit parameters, we apply the same fitting procedure to 10^3 simulated astrometric data sets at the same epochs but with randomly drawn noise added. We measure a proper motion of μ = 151 ± 8 mas/yr at a position angle of 33 ± 4°. This proper motion is consistent with fitting for the proper motion only based on catalog positions with larger uncertainties. Although including parallax was necessary to accurately model the data, our simulations show that it is not measured at a high precision ($\pi_{\rm rel} = 107 \pm 34$ mas). Thus, we continue to adopt

[2] We obtained poor fits using the PHOENIX-*GAIA* atmospheric models (Brott & Hauschildt 2005) which do not include the effects of dust.

[3] Our $L_{\rm bol}$ measurement from the entire SED agrees well with that inferred from using the K-band bolometric corrections (BC_K) from Golimowski et al. (2004) as revised by Liu, Leggett & Dupuy (2009, submitted). Using BC_K with the observed K-band magnitude and L6±0.5 spectral type gives $\log(L_{\rm bol}/L_\odot)$ = –4.42 ± 0.04 (0.21) dex, if one ignores (includes) the distance error.

[4] Details about the UKIDSS project can be found in Lawrence et al. (2007), Casali et al. (2007), Hewett et al. (2006), Hodgkin et al. (2009), and Hambly et al. (2008). We have used data from the 6th Data Release.

the more precise photometric distance estimate of 8.4 ± 1.9 pc, which is consistent with our astrometric analysis.

Our proper motion measurement and distance estimate can be combined with the radial velocity of SDSS J1416+1348 to derive UVW kinematics. The radial velocity reported by SDSS is –88 ± 33 km s^{-1}, which is derived by cross correlation with a late-type stellar spectrum. To improve upon this, we fit Gaussians to the Rb I (7800, 7948 Å), Na I (8183, 8195 Å), and Cs I (8521, 8943 Å) absorption lines, convert line centers from heliocentric vacuum wavelengths to air wavelengths using the IAU standard conversion in Morton (1991), and compute a radial velocity using the rest wavelengths in Ralchenko et al. (2008). We obtain internally consistent values with a mean and rms velocity of –38 ± 10 km s^{-1}, which is consistent with the SDSS radial velocity at the 2 σ level. Using our solar-metallicity spectrophotometric distance estimate of 8.4 ± 1.9 pc and our radial velocity measurement we find $(U, V, W)_{\rm LSR}$ velocity components of (6 ± 4 km s^{-1}, 10.2 ± 1.4 km s^{-1}, –27 ± 9 km s^{-1}). Here U is positive towards the galactic anticenter. The velocities are calculated following Johnson & Soderblom (1987) and are corrected for the solar motion with respect to the local standard of rest using the values from Dehnen & Binney (1998, $UVW_\odot$ = {–10.00, +5.25, +7.17}). Errors are computed in a Monte Carlo fashion from 10^6 trials and are dominated by the radial velocity uncertainty.

We derive the probability that SDSS J1416+1348 is a member of the thin disk, thick disk, or halo kinematic population using the Besançon Galactic model (Robin et al. 2003). The UVW velocities of SDSS J1416+1348 imply a 99.1% (0.9%) probability of having a thin (thick) disk membership, with a negligible halo membership, based on the method discussed in Dupuy et al. (2009). Similarly, the Toomre diagram from Venn et al. (2004, note the galactic standard of rest) suggests a Galactic thin disk orbit.

4. DISCUSSION

Three mechanisms have been proposed to cause the peculiar NIR colors of blue L dwarfs: low metallicity, unresolved multiplicity, or thin/large grain condensate clouds. As discussed in Burgasser et al. (2008b), a high surface gravity will also cause blue NIR colors in L dwarfs, but current model atmospheres with high surface gravity fail to reproduce the deep H_2O absorption features observed in many blue L dwarfs. A significantly reduced metallicity for SDSS J1416+1348 is unlikely based on the shallow depth of the metallicity-dependent TiO and CaH absorption bands in its optical spectrum. Similarly, the NIR spectrum of SDSS J1416+1348 does not exhibit the extreme collision-induced H_2 absorption seen in the spectra of known L subdwarfs. All known L subdwarfs also have inner or outer halo orbits, but the kinematics of SDSS J1416+1348 implies a thin disk orbit. Another possibility is that SDSS J1416+1348 is only mildly metal-poor, but slightly low-metallicity atmospheric models do not predict the deep NIR H_2O bands observed in SDSS J1416+1348 (Burgasser et al. 2008b; Burrows et al. 2006).

Burgasser et al. (2008b) found that unresolved multiplicity is not likely to be the cause of the blue NIR colors of 2MASS J1126–5003 based on composite binary spectral template fitting. Because of the similarity of the NIR spectra of SDSS J1416+1348 and 2MASS J1126–5003 (Figure 2), and because the spectrum of SDSS J1416+1348 does not show the characteristic feature of unresolved M/L + T binaries at 1.6 μm (Burgasser et al. 2008a), it is also unlikely that unresolved multiplicity is the cause of the blue NIR colors of SDSS J1416+1348.

We find that the most likely explanation for the peculiar colors of SDSS J1416+1348 is a reduced condensate opacity caused by thin or large-grain clouds. This is supported by the abnormally strong 1.4 and 1.9 μm H_2O features, which can only be reconciled with atmospheric models that contain large grains (Burrows et al. 2006) and/or thin clouds (Stephens et al. 2009). The 0.99 μm FeH feature of SDSS J1416+1348 has almost exactly the same depth as in 2MASS J1126–5003, both of which are significantly stronger than in normal L dwarfs. As discussed in Folkes et al. (2007) and Burgasser et al. (2008a), this deep FeH is further evidence for a peculiar cloud structure in blue L dwarfs.

It appears that previous searches for L dwarfs missed SDSS J1416+1348 because of its small proper motion and peculiar colors, despite its bright NIR magnitudes. Recently Zhang et al. (2009) performed a search for ultracool dwarfs in SDSS DR7 but SDSS J1416+1348 was missed because of their bright i- and z-band magnitude cuts. Many of the SDSS-only and SDSS cross-matching searches were performed with early data releases which did not include SDSS J1416+1348 (e.g., Chiu et al. 2006), as SDSS J1416+1348 has imaging observations from May 2003 and spectroscopic observations from March 2005. Cruz et al. (2003) performed a series of 2MASS, Tycho, and USNO color and magnitude cuts to search for L dwarfs within 20 pc (also see footnote 14 in Cruz et al. 2007). SDSS J1416+1348 appears to pass the magnitude and color criteria in that search so it is unclear why it was not found. SDSS has surveyed nearly one quarter of the sky; because only one bright, blue L dwarf with a small proper motion has been found to date, we suspect that at most a handful of objects like SDSS J1416+1348 await discovery.

Based on its spectrophotometric distance, SDSS J1416+1348 is one of the nearest L dwarfs to the Sun (Figure 3, bottom panel; see also Faherty et al. 2008) and with a J-band magnitude of 13.148 it is one of the brightest late-type L dwarfs known. Its proximity makes it an excellent target for follow-up parallax measurements, radial velocity measurements, adaptive optics imaging observations, and high resolution, high signal-to-noise optical and NIR spectroscopic observations.

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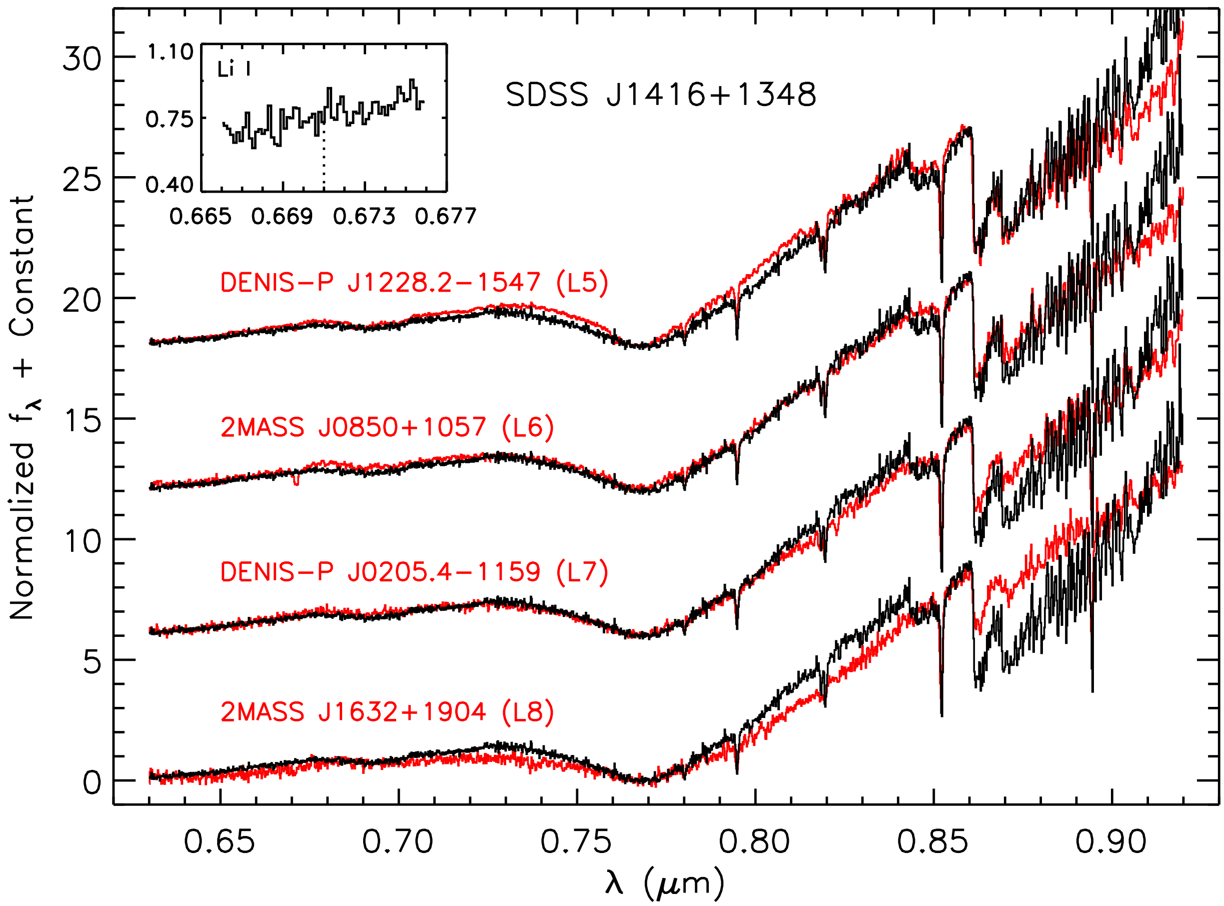

Fig. 1.— SDSS optical spectrum of SDSS J1416+1348 (black). Overplotted are the spectra of L5-L8 dwarf templates from Kirkpatrick et al. (1999, red). SDSS J1416+1348 is most similar to the L6 dwarf 2MASS J0850+1057. The inset shows the nondetection of Li I at 6708 Å. All spectra are normalized to unit area between 6300-9200 Å and are offset for clarity.

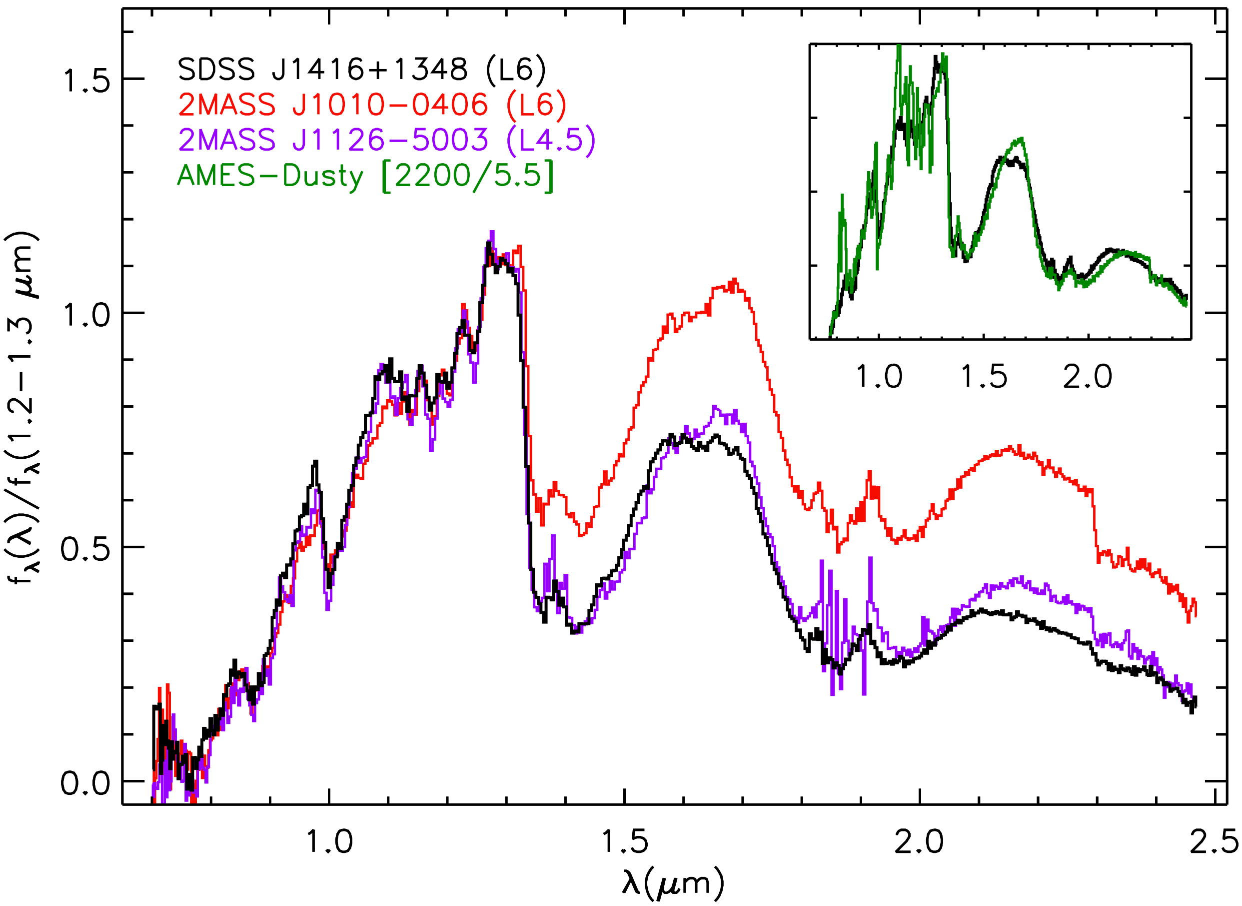

Fig. 2.— Near infrared spectrum of SDSS J1416+1348 from IRTF/SpeX in prism mode (black). Overplotted are the SpeX/prism spectra of the L6 dwarf 2MASS J1010–0406 (Reid et al. 2006, red), which has J-K_S colors similar to normal L dwarfs ($\sim$ 1.9 mags), and the blue L4.5 dwarf 2MASS J1126–5003 (Burgasser et al. 2008b, purple). All spectra are normalized to the same flux from 1.2-1.3 μm. The inset shows the best-fitting AMES-Dusty model with $T_{\rm eff}$ = 2200 K and log g = 5.5 (green).

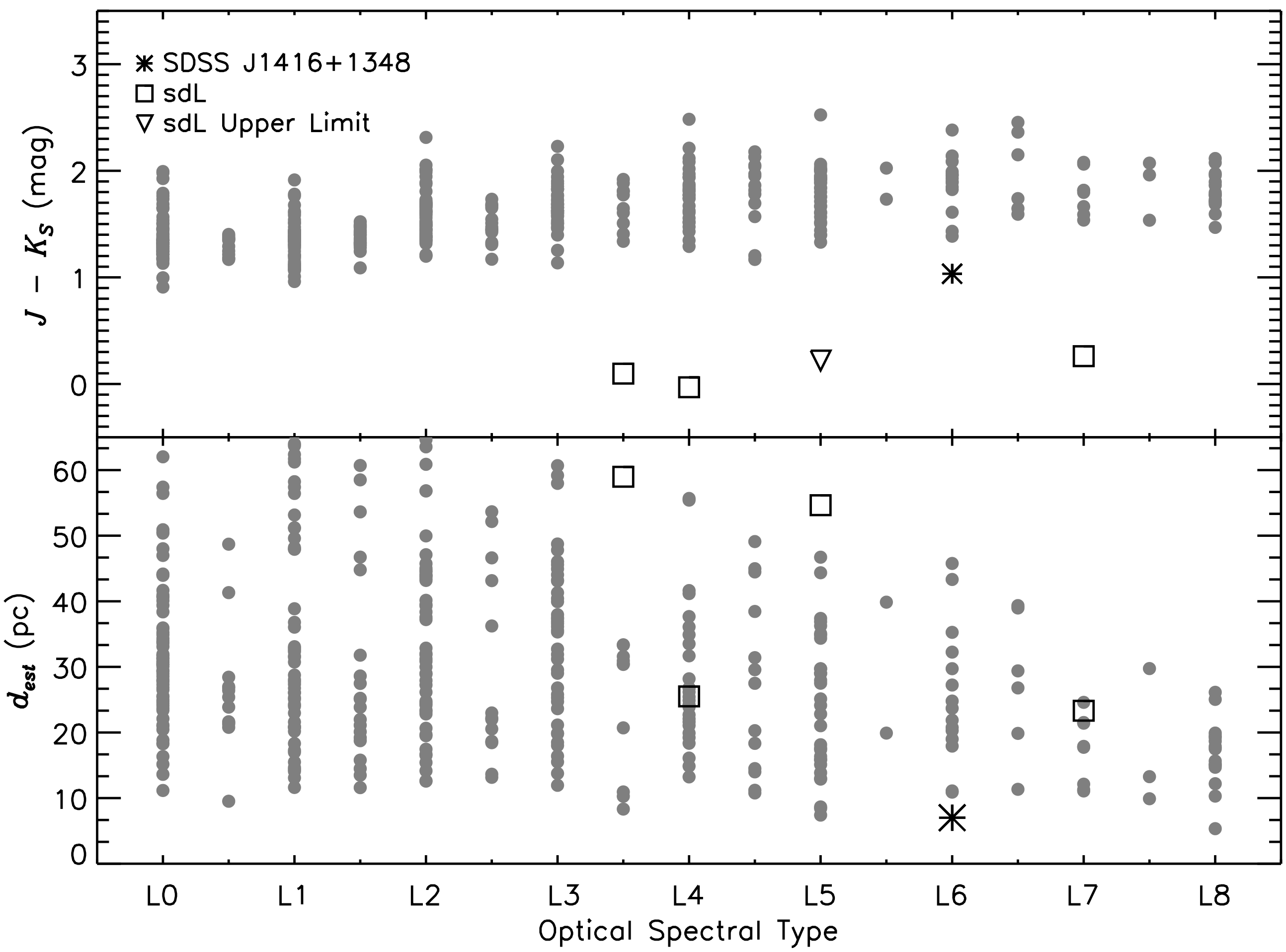

FIG. 3.— *Top panel:* J–K_S colors for L dwarfs from http://dwarfarchives.org as of April 2009. L subdwarfs are shown as open symbols while SDSS J1416+1348 is shown as an asterisk. For late-L spectral types, blue L dwarfs have J–K_S colors of ~ 1.0, while known L subdwarfs have J–K_S colors of ~ 0.0. The open squares show the colors of known L subdwarfs and the open triangle shows the upper limit for the L subdwarf 2MASS J06164006–6407194. *Bottom panel:* J-band spectrophotometric distances to L dwarfs from http://dwarfarchives.org. For field L dwarfs we use the relations from Tinney et al. (2003); for L subdwarfs we use the relations from Cushing et al. (2009). Symbols are the same as in the upper panel.

TABLE 1
SDSS J1416+1348 Properties

Property	Value
Observed	
α_{J2000}[a]	$14^{h}16^{m}24\overset{s}{.}08$
δ_{J2000}[a]	$13°48'26\overset{''}{.}7$
Epoch	2003.41
Optical SpT	L6.0 ± 0.5
NIR SpT	L6.0pec ± 2.0
μ (mas yr^{-1})	151 ± 8
PA (°)	33 ± 4
$V_{\rm rad}$ (km s^{-1})	–38 ± 10
u (SDSS)	(23.55 ± 0.57)[b]
g (SDSS)	(23.08 ± 0.18)[b]
r (SDSS)	20.69 ± 0.04
i (SDSS)	18.38 ± 0.01
z (SDSS)	15.92 ± 0.01
R (USNO-B1.0)	19.68
I (USNO-B1.0)	17.22
Y (UKIDSS)	14.255 ± 0.003
J (2MASS)	13.148 ± 0.025
H (2MASS)	12.456 ± 0.028
$K_{\rm S}$ (2MASS)	12.114 ± 0.023
Estimated	
$d_{\rm est}$[c]	8.4 ± 1.9 pc
$\log(L_{\rm bol}/L_{\odot})$	–4.36 ± 0.21 (0.02)[d]
U[e] (km s^{-1})	6 ± 4
V (km s^{-1})	10.2 ± 1.2
W (km s^{-1})	–27 ± 9

Note. — u, g, r, i, and z are in AB magnitudes; J, H, and $K_{\rm S}$ are in the 2MASS system; and Y is the UKIRT/WFCAM Y-band filter.
[a] Measured by SDSS.
[b] Near the faint limit of SDSS and may not represent an actual detection. The quoted value is the inverse hyperbolic sine magnitude (*asich*), which for high signal-to-noise measurements is the same as the canonical astronomical magnitude.
[c] Average of the J- and $K_{\rm S}$-band spectrophotmetric distances.
[d] The error in parentheses excludes the uncertainty in the distance.
[e] Positive toward galactic anticenter.